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Radiological exposure of patients undergoing transcatheter aortic valve implantation in contemporary practice

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Abstract: BACKGROUND Radiological exposure associated with transcatheter aortic valve implantation (TAVI) is unknown and might impact on broadening indications to lower risk patients. Radiological exposure of TAVI patients and its predictors are herein reported. METHODS Radiological exposure derived from exams/procedures performed within 30 days preceding/following TAVI were acquired and converted into effective-dose. Total effective-dose was defined as the sum of each single dose derived from diagnostic/therapeutic sources. Univariable and multivariable analyses were performed to recognize correlates of exposure. RESULTS Seventy-five patients aged 82.6 ± 6.0 years with a median Euroscore II 3.6 [IQR 1.93-6.65] were analysed. Median total effective-dose was 41.39 mSv [IQR 27.93-60.88], with TAVI accounting for 47% of it. Age (coefficient -0.031, 95% CI -0.060 to -0.002; P = 0.031) and previous history of cerebrovascular accidents (CVA; coefficient -0.545; 95% CI -1.039 to -0.010; P = 0.046) resulted as inversely correlated to total effective-dose (log-transformed), whereas left ventricular ejection fraction (LVEF) less than 50% (coefficient 0.430, 95% CI 0.031-0.828; P = 0.035) was directly associated. CONCLUSION Multiple radiological sources are responsible for the observed exposure, with TAVI being the prominent source. Age is inversely related to the radiological exposure.

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Original article

Radiological exposure of patients undergoing transcatheter aortic valve implantation in contemporary practice

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Conclusion **Multiple radiological sources are responsible for the observed exposure, with TAVI being the prominent source. Age is inversely related to the radiological exposure.**

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Keywords: aortic stenosis, effective dose, radiation, transcatheter aortic valve implantation, transcatheter aortic valve replacement

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Introduction

The introduction of techniques allowing the percutaneous replacement of a stenotic aortic valve represented one of the major advancements of interventional cardiology in recent years.

Transcatheter aortic valve implantation (TAVI) was originally offered as an alternative to medical therapy in elderly patients at extreme or high surgical risk. Its huge therapeutic potential allowed the demonstration of, on short-term outcomes, a reduction in mortality in nonoperable patients and noninferiority to surgery in high-risk patients.[1,2]

Justified by that initial evidence, an exponential increase in procedures was observed,[3] this was associated with a progressive widening of the indications, resulting in a concomitant decrease in patient's complexity.[4–6]

Thus, future adoption of this technique as the therapy of choice for an all-comer population with severe aortic stenosis seems to be a potential perspective,[7] also justified by the great advances obtained in the optimization of procedural outcomes.[8]

Nonetheless, almost no relevance has been given so far to the amount and potential long-term effects of X-ray exposure during TAVI, an aspect considered of little clinical significance, due to the presumed low risk of clinically evident effects.

Few retrospective analyses report on the procedural radiological exposure of those patients, neglecting that a complex preprocedural work-up and postprocedural phase might significantly impact on the total exposure.[9,11] In light of a more widespread use of TAVI in younger patients, radiological exposure cannot be disregarded any longer, needs to be provided as a part of the information given to patients and has to play a role in the decision between TAVI vs. traditional surgical approaches.

Thus, the aim of this article is to describe the total radiological exposure observed in a contemporary series of TAVI patients and to recognize predictors of increased exposure.

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Methods

Patient population

All patients with severe symptomatic aortic valve stenosis with complete data on the fluoroscopic exposition who have been treated with TAVI procedures at our Institution between 1 January 2015 and 31 May 2016 were considered in the present analysis. Clinical data and procedural details were prospectively collected according to Swiss TAVI Registry requirements, and analysed. Data on radiological exposure derived from all exams/procedures performed within 30 days preceding/following the implant procedure have been acquired from the on-site data system. Written informed consent for the TAVI procedure and data acquisition were signed by all patients.

Patient workflow

Before final candidacy for TAVI, surgery or medical therapy, each patient has to undergo a definite preprocedural work-up in order to confirm the clinical indication, plan the procedure and foresee potential challenges. Transthoracic and transoesophageal echocardiography as well as a diagnostic coronary angiography and a contrast-enhanced computed tomography (CT) scan are performed in all suitable patients before heart team discussion. Additional radiological examinations/procedures (e.g. chest X-ray, adjunctive CT scan, unplanned coronary angiography, pacemaker implantation, etc.) are performed both preprocedurally and postprocedurally, when deemed clinically necessary.

In patients with an estimated glomerular filtration rate less than 40 ml/kg/min, angiographic examinations are reduced to the strictly necessary, withholding angio CT scans in the vast majority of cases and echo data are used to plan the procedure.

Coronary angiography

Coronary angiography is performed through the radial access with a set of three cine projections for the right coronary artery and six for the left. When TAVI is considered as an option, aortography (LAO 30°) and an angiography in the AP projection of the iliofemoral vessel is also performed. When revascularization is deemed necessary, percutaneous coronary interventions (PCI) are performed on the same or on a staged procedure. Both for cine and fluoroscopy frame, the rate is set at 15 frame/s and all images are acquired on a Philips Allura Clarity X-ray unit (Philips, Best, The Netherlands). Regular calibration of the radiological equipment was performed.

Computed tomography scan

Preprocedural CT imaging is performed on a 128 detectors dual-source CT (Somatom Force; Siemens Healthcare, Forchheim, Germany) to evaluate the anatomy of the aortic annulus and access vessels using a prespecified protocol.[12] An ECG-triggered high-pitch spiral acquisition is performed (250 ms gantry rotation, 66 ms temporal resolution, $2 \times 192 \times 0.6$ collimation, tube voltage 120 kV, tube current 350–500 mA depending on weight). Scan direction is craniocaudal from above the aortic arch to below the hip. After a test bolus to evaluate the contrast agent transit time, 80 ml of dye is injected in an antecubital vein with a flow rate of 5 ml/s. Images are reconstructed using a slice thickness of 0.6 mm, and an increment of 0.4 mm.

On the basis of CT scan data, annular dimensions are measured and navigability of the ileofemoral arteries is ascertained. The angiographic projection showing the three hinge points of the aortic cusps is searched and suggested to the interventional cardiologist as a potential implant view.[12]

Transcatheter aortic valve implantation procedure

All procedures have been performed in a hybrid room with an Allura Philips fluoroscopy system by a team of four operators with expertise on coronary and structural interventions. Each operator had a personal background of more than 200 TAVI implants. Procedures were performed with a standard fluoroscopy-guided implant procedure. Fluoroscopic acquisition was set at 15 f/s. The reliability of the implant view predicted with CT scan was ascertained with a cine aortography. In case of unsatisfactory alignment, another implant view by means of multiple angiographies was chosen.

Release of retrievable valves was performed during continuous fluoro imaging or cine recordings with repeated dye injections to constantly monitor the valve position. For balloon expandable valves, balloon inflation and deflation were recorded with cine.

Effective-dose estimation

The equation $ED = OQ \times CF$, where $OQ =$ operational quantity, and $CF =$ conversion factor were used for the estimation of the effective-dose.

To convert the dose area product data provided by angiographic equipment, the CF of 0.24 mSv/Gy cm^2 published by Karambatsakidou *et al.*[10] was used, whereas for the dose length product conversion the CFs published by Deak *et al.* were used.[13] CF used to calculate effective-dose for traditional X-ray examinations were derived from Heron.[14]

Total effective-dose was defined as the sum of each single effective-dose derived from diagnostic or therapeutic sources in the 30 days preceding or following the TAVI procedure.

Statistical analysis

Data are described as mean and standard deviation or the median and interquartile range (IQR) if continuous, and counts and percentage if categorical. Generalized linear regression models to identify correlates of total effective-dose were used; given the skewed distribution, the latter was log-transformed. All noncollinear variables with a P less than 0.1 at the univariable analysis were included in a multivariable model. The choice between collinear predictor was based on clinical knowledge. A model fit was graphically assessed by using residuals. A two-sided P value less than 0.05 was considered statistically significant. Stata 14 (StataCorp, College Station, Texas, USA) was used for computations.

Results

Patient population

Seventy-five patients with a mean age of 82.6 ± 6.0 years and an intermediate-to-low surgical risk (median Euroscore II 3.6 [IQR 1.93–6.65]) treated with TAVI at our site were evaluated. Baseline clinical and echocardiographic characteristics are reported in Table 1.

All except one patient underwent a preprocedural coronary angiography during the work-up phase: in 10 cases (13.3%) coronary angiography was followed by PCIs whereas in one patient, a balloon aortic valvuloplasty was performed as a bridge to TAVI. In 66 cases (88%), a contrast-enhanced CT angiography was performed.

The vast majority of TAVI were performed through a percutaneous transfemoral approach (92%). In about two-thirds of cases, a self-expandable valve was implanted. An overall low complication rate was observed with one intraprocedural death. In two cases, surgical repair of the femoral artery was needed; no peripheral interventions to repair access site complications, that could have significantly increased exposure were performed. Table 2 reports on the details related to the TAVI procedure. During the postprocedural phase, a repeated angiographic examination was deemed necessary in two patients, whereas a percutaneous mitral valve repair and a percutaneous mitral valve dilatation were performed in two distinct patients.

Radiological exposure

Table 3 shows the radiological exposure derived from diagnostic sources, therapeutic procedures and TAVI implantation.

The median total effective-dose of patients treated with TAVI was 41.39 mSv [IQR 27.93–60.88]. Distribution of total radiological exposure was skewed with 86% receiving less than 100 mSv and 10 patients showing an exposure greater than 100 mSv (Fig. 1).

TAVI implant resulted as the prevalent source of radiological exposure, with a median effective-dose of 16.11 mSv [IQR 10.54–27.70] per procedure, accounting for almost half of the total exposure.

Contrast-enhanced cardiac and angio CT scans were performed in 88% of patients, whereas other CT scans were needed in the preprocedural or postprocedural phase in 22.6% of patients (cerebral CT scan in 15,

Table 1 Patients' clinical characteristics

Clinical characteristics	
Patients, (*n*)	75
Male sex, *n* (%)	43 (57.3)
Age, years	82.6 ± 6.0
Height, cm	164.3 ± 8.9
Weight, kg	71.9 ± 13.7
BMI	26.6 ± 4.7
BMI >30, *n* (%)	20 (26.6)
Body surface area, m^2	1.8 ± 0.2
Comorbidities	
Diabetes, *n* (%)	23 (30.6)
Hypertension, *n* (%)	67 (89.3)
End stage renal failure, *n* (%)	1 (1.3)
Creatinine (μmol/l), mean ± SD	110 ± 61
eGFR (ml/min/1.73 m^2), mean ± SD	52 ± 25
Dyslipidaemia, *n* (%)	51 (68.0)
Known coronary artery disease, *n* (%)	44 (58.7)
Previous PCI, *n* (%)	27 (36.0)
Atrial fibrillation, *n* (%)	11 (14.7)
Left ventricular ejection fraction less than 50%, *n* (%)	26 (36.6)
Chronic obstructive pulmonary disease, *n* (%)	11 (14.7)
Previous cerebrovascular disease, *n* (%)	6 (8.0)
Previous pacemaker implant, *n* (%)	8 (10.7)
Previous ICD implant, *n* (%)	0 (0)
Clinical presentation	
Dyspnoea, *n* (%)	64 (85.3)
NYHA III and IV, *n* (%)	45 (60.0)
Angina, *n* (%)	10 (13.3)
Syncope, *n* (%)	3 (4.0)
Cardiogenic shock, *n* (%)	3 (4.0)
Echocardiographic data	
LVEF, %	51.1 ± 12.0
Peak AV gradient, mmHg	72.2 ± 25.3
Mean AV gradient, mmHg	47.1 ± 17.7
Anatomic aortic valve area, cm^2	0.7 ± 0.2
Preoperative surgical risk	
Euroscore I logistic	14.76 [IQR 8.46–22.0]
Euroscore I linear	10.00 [IQR 8.00–11.00]
Euroscore II	3.6 [IQR 1.93–6.65]
STS score	3.7 [IQR 2.47–5.95]

AV, Aortic Valve; eGFR, estimated glomerular filtration rate; ICD, Implantable Cardioverter Device; LVEF, left ventricular ejection fraction; NYHA, New York Heart Association class; PCI, percutaneous coronary interventions; STS, Society of Thoracic Surgeons' risk score.

Table 2 Transcatheter aortic valve implantation procedural parameters

Procedural parameters	
Procedural time, min	101.7 ± 34.0
Contrast volume, ml	350 [IQR 250.0–442.5]
Access type	
Transfemoral, *n* (%)	69 (92.0)
Direct aortic, *n* (%)	4 (5.3)
Transapical, *n* (%)	2 (2.7)
Type of valve	
Balloon expandable, *n* (%)	29 (38.6)
Edwards Sapien 3	29
Self expandable, *n* (%)	46 (62.4)
Medtronic Corevalve	14
Medtronic Evolut R	14
BSC Lotus	13
Symetis Accurate	4
Jenavalve	1
Procedural complications	
Cardiac tamponade, *n* (%)	1 (1.3)
Hemodynamic instability requiring resuscitation, *n* (%)	1 (1.3)
Access vessel complication, *n* (%)	2 (2.6)
Valve in valve, *n* (%)	3 (3.9)
Intraprocedural death, *n* (%)	1 (1.3)

Table 3 Radiological exposure

Total exposure	
Additive effective-dose, mSv	41.39 [IQR 27.93–60.88]
Patients with total dose exceeding 100 mSv, *n* (%)	10 (13.3)
Procedural exposure during TAVI	
Fluoro time, min	23.3 [IQR 18.7–27.5]
Effective-dose, mSv	16.11 [IQR 10.54–27.70]
Nonprocedural-related exposure	
Coronary angiographies/PCI, *n* (%)	74 (98.6)
Total fluoro time, min	8.50 [IQR 4.93–14.48]
Effective-dose, mSv	7.86 [IQR 3.80–16.75]
Cardiac CT scans	66 (88.0)
Effective-dose, mSv	8.56 [IQR 7.40–9.26]
Other CT scans[a], *n* (%)	17 (22.6)
Other CT scan derived effective-dose, mSv	4.5 [IQR 2.1–9.3]
Total CT scan derived effective-dose, mSv	8.9 [IQR 8.0–13.5]
Permanent pacemaker implants, *n* (%)	12 (16.0)
Total fluoro time, min	4.66 ± 2.20
Effective-dose, mSv	3.8 [IQR 2.79–4.5]
Standard radiological examinations, *n* (%)	70 (93.3)
Effective-dose, mSv	0.18 [IQR 0.11–0.34]

CT, computed tomography. [a] Chest CT/brain CT/abdomen CT scans.

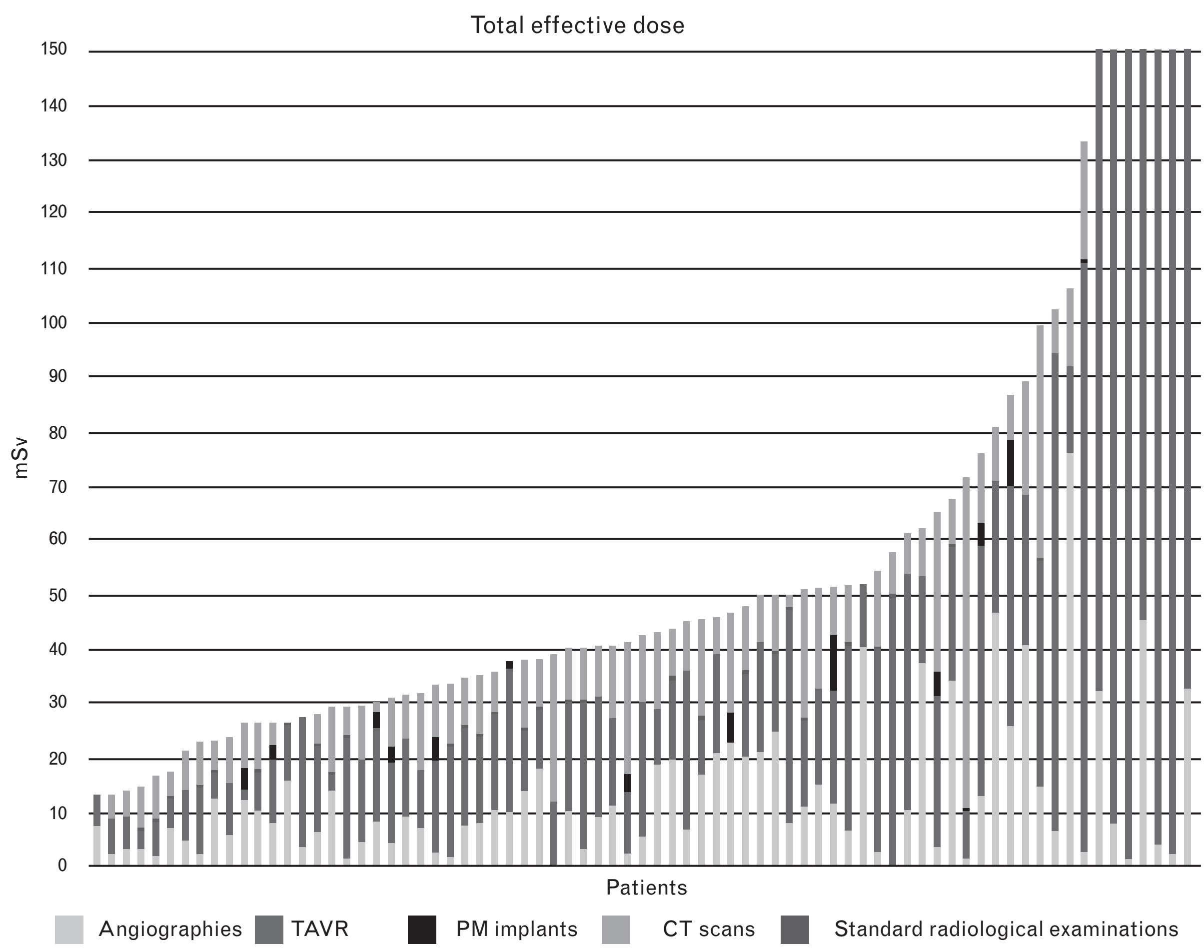
pulmonary angio CT in 4, chest CT in 2, abdominal CT scan in 6 patients). The median effective-dose derived from preprocedural and postprocedural CT examination amounted to 8.9 mSv [IQR 8.0–13.5], almost 25% of the total exposure.

Coronary angiography and/or PCI performed either before or after TAVI represented the third source of exposure with a median effective-dose of 7.86 mSv [IQR 3.80–16.75].

Data regarding radiological exposure derived from pace maker implantations as well as from standard radiological exams are reported in Table 3, whereas Fig. 2 describes the relative impact on total exposure according to the source.

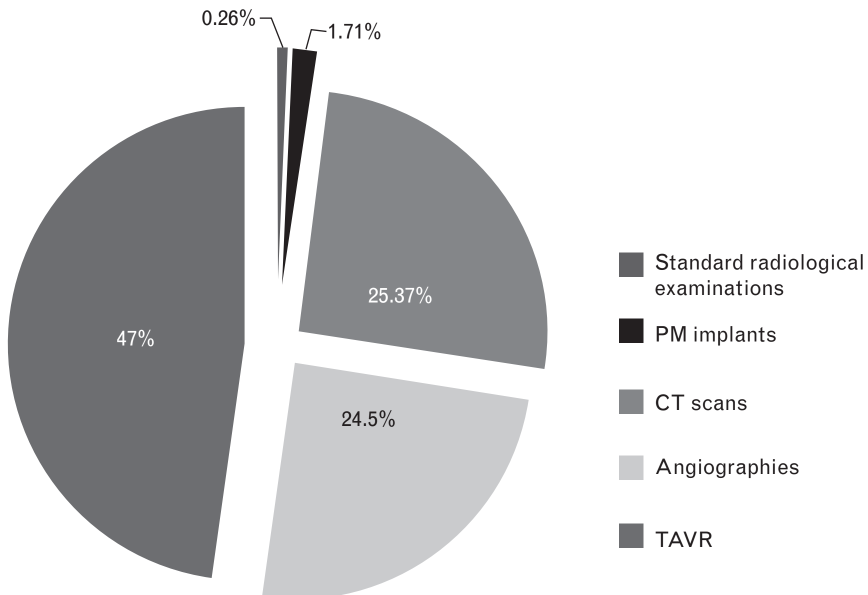
During hospitalization or at 1-month follow-up, none of the patients showed signs suggestive of deterministic effects (skin erythema, irreversible skin damage, chest hair loss or cataract) related to the periprocedural or intraprocedural radiological exposure.

Fig. 1



Distribution of the total effective dose according to different sources. Vertical bars represent single patients.

Fig. 2



Relative impact of each exam/procedure on total exposure.

Correlates of total radiological exposure

Table 4 reports the results of the univariable and multivariable analysis. Male sex (coefficient 0.383, 95% CI 0.022–0.745; $P=0.010$), and reduced left ventricular ejection fraction (LVEF < 50%; coefficient 0.497, 95% CI 0.117–0.876; $P=0.011$) were associated with increased total additive effective-dose (log-transformed), whereas age (per year) was inversely correlated

Table 4 Univariable and multivariable analysis

	Univariable			Multivariable		
Variable	Coefficient	95% Confidence interval	*P*	Coefficient	95% Confidence interval	*P*
Male	0.383	0.022–0.745	**0.010**	0.221	−0.136 to 0.578	0.221
Age	−0.038	−0.068 to −0.009	**0.010**	−0.031	−0.060 to −0.002	**0.031**
BMI >30	0.381	−0.025 to 0.788	0.065	0.342	−0.091 to 0.776	0.120
Diabetes	0.345	−0.045 to 0.736	0.083	0.191	−0.258 to 0.641	0.398
Hypertension	0.255	−0.337 to 0.848	0.394			
Dyslipidaemia	0.301	−0.086 to 0.690	0.126			
Known CAD	0.254	−0.114 to 0.623	0.173			
History of PCI	0.107	−0.275 to 0.490	0.578			
History of atrial fibrillation	−0.004	−0.524 to 0.515	0.986			
COPD	0.096	−0.423 to 0.615	0.714			
Previous pace maker	−0.141	−0.737 to 0.453	0.637			
End stage renal failure	0.375	−1.226 to 1.978	0.642			
History of CVA	−0.614	−1.227 to 0.048	0.069	−0.525	−1.039 to −0.010	**0.046**
Mean aortic gradient	−0.004	−0.015 to 0.006	0.403			
LVEF <50%	0.497	0.117–0.876	**0.011**	0.430	0.031 to 0.829	**0.035**
Dyspnoea	0.221	−0.296 to 0.739	0.397			
Stable angina	−0.240	−0.778 to 0.298	0.377			
Syncope	0.087	−0.851 to 1.026	0.854			
Cardiogenic shock	0.050	−0.889 to 0.989	0.915			
Transfemoral access	0.381	−0.301 to 1.064	0.269			
Balloon expandable	−0.065	−0.454 to 0.324	0.740			
Valve in Valve	−0.300	−1.250 to 0.649	0.530			
TAVI procedural time	0.002	−0.002 to 0.008	0.301			
Logistic ES I	0.003	−0.008 to 0.015	0.590			
Linear ES I	0.015	−0.049 to 0.079	0.634			
Euroscore II	0.013	−0.016 to 0.042	0.382			
STS score	−0.000	−0.040 to 0.039	0.981			

COPD, chronic obstructive pulmonary disease; CVA, cerebrovascular accidents; LVEF, left ventricular ejection fraction; PCI, percutaneous coronary interventions; TAVI, transcatheter aortic valve implantation. Statistically significant values in bold.

(coefficient −0.038, 95% CI −0.068 to −0.009; $P = 0.010$). BMI greater than 30, diabetes and history of cerebrovascular accidents (CVA) were borderline nonsignificant. The implantation of balloon expandable as compared to self expandable valves did not result in an increased dose.

At multivariable analysis, age (per year, coefficient −0.031, 95% CI −0.060 to −0.002; $P = 0.031$) and previous history of CVA (coefficient −0.545; 95% CI −1.039 to −0.010; $P = 0.046$) resulted as inversely correlated to total effective-dose (log transformed), whereas LVEF less than 50% (coefficient 0.430, 95% CI 0.031–0.828; $P = 0.035$) was directly associated.

Discussion

The main findings of our study are as follows:

(1) Multiple radiological exams and procedures are responsible for the exposure observed in TAVI patients, with implant procedure being the prominent source.
(2) Age is inversely related to the radiological exposure, with younger patients receiving higher doses.

Our article reports not only the intraprocedural data but also the detailed quantification of the total TAVI-related burden of X-ray exposure including the preprocedural work-up, the implant and the postprocedural phase. In addition, predictors of increased exposure were identified.

Our data revealed that a significant X-ray exposure of patients treated with TAVI derives from multiple sources. A median of 16.1 mSv was delivered to patients during the implant, accounting for almost 50% of the total exposition and in line with previous reports.[10] Putting those data into perspective, this exposure is comparable with the average 19.4 mSv individual cumulative dose of nuclear plant employees received over their entire career.[15]

Such a significant exposure represents a clear indication for the development and the implementation of institutional low-dose protocols to minimize procedural exposure leading to a significant reduction in exposure during percutaneous coronary interventions.[16]

Nonetheless, although being the most important source of X-ray, TAVI implant represents just one of different sources to which patients are exposed during the preprocedural work-up or the postimplant phase. A median additive effective-dose of 41.39 mSv was measured in our population with almost 15% of patients exposed to a total dose exceeding 100 mSv. This massive exposure has been recognized to induce deterministic effects and to significantly increase by 10% the relative risk of solid cancers and by 19% of leukaemia in a large dosimetric study.[15]

Thus, optimization of the radiological exposure should not be limited to the implant procedure but extended to the entire preprocedural work-up and postprocedural phase. In fact, common practice is to evaluate all patients undergoing TAVI with both a coronary angiogram and an ECG-gated angio CT for annular measurement. As evident from our data, only less than 60% of patients had a known history of coronary artery disease, whereas the remaining could have been screened for by careful analysis of the angio CT scan, scheduling for invasive angiography only those with a clear suspicion of significant coronary disease. Accurate analysis of CT scan data has shown a high sensitivity and negative predictive value in excluding obstructive coronary artery disease, thus avoiding the need for preprocedural angiographic examination in TAVI candidates with nonobstructive disease at preprocedural CT scan.[17,18]

Not surprisingly, patient's age resulted inversely correlated with total exposure, meaning that younger patients are those receiving greater doses. Our data demonstrate that a reduction of 10 years in age corresponds to a 30% increase of the log-dose, thus with a potential detrimental long-term effect for younger patients. This evidence might be a consequence of several concomitant factors such as the desire of obtaining a more extended revascularization prior to the TAVI procedure, the possibility to perform multiple percutaneous procedures, or a preserved renal function thus allowing a more liberal adoption of preprocedural CT scans or angiographic examinations. Nonetheless, because of the retrospective nature of our analysis, any potential implication remains speculative.

Risk of fatal and nonfatal malignancies associated with radiological exposures in TAVI might represent a negligible hazard whether observed from a local standpoint. Nonetheless, if considered from a continental or global perspective, tangible effects of this exposure might become already manifest at the present stage, with a current volume of TAVI procedures estimated to be of more than 70 000 so far[19] and with a trend expected to skyrocket in the next future.

Limitations

The retrospective nature of our work does not allow the drawing of definite conclusions but data have to be considered as hypothesis-generating and the small sample size might impact on dose estimations.

Moreover, evaluation of the effective dose for TAVI procedures is based on several assumptions and is thus associated with uncertainties in dose estimates, so this should be considered as approximations to guide clinical decision. Finally, although this article aims at sensitizing the cardiological community on the patient's related risks associated with radiological exposure, evaluation of the professional exposure is beyond our scope.

In conclusion, this is the first report giving a total estimation of the radiological exposure and of the exposure-related risk of fatal lung cancer derived from a contemporary TAVI series.

Present data allow the rationalizing of exposure of TAVI patients, to extend information given to patients prior to the procedure in terms of additive radiological risk, as well as to increase the awareness of the cardiological community towards this significant source of exposure aiming at protecting patients and health professionals.

Acknowledgements

Conflicts of interest

There are no conflicts of interest.

References

1 Leon MB, Smith CR, Mack M, *et al.*, PARTNER Trial Investigators. Transcatheter aortic valve implantation for aortic stenosis in patients who cannot undergo surgery. *N Engl J Med* 2010; **363**:1597–1607.
2 Smith CR, Leon MB, Mack MJ, *et al.*, PARTNER Trial Investigators. Transcatheter versus surgical aortic valve replacement in high-risk patients. *N Engl J Med* 2011; **364**:2187–2198.
3 Dudek D, Barbato E, Baumbach A, *et al.* Current trends in structural heart interventions: an overview of the EAPCI registries. *EuroIntervention* 2017; **13 (Z)**:Z11–Z13.
4 Adams DH, Popma JJ, Reardon MJ, *et al.*, U.S. CoreValve Clinical Investigators. Transcatheter aortic valve replacement with a self-expanding prosthesis. *N Engl J Med* 2014; **370**:1790–1798.
5 Leon MB, Smith CR, Mack MJ, *et al.*, PARTNER 2 Investigators. Transcatheter or surgical aortic-valve replacement in intermediate-risk patients. *N Engl J Med* 2016; **374**:1609–1620.
6 Abdelghani M, Serruys PW. Patient selection for TAVI in 2016: should we break through the low-risk barrier? *EuroIntervention* 2016; **12**:Y46–Y50.
7 Thyregod HG, Steinbrüchel DA, Ihlemann N, *et al.* Transcatheter versus surgical aortic valve replacement in patients with severe aortic valve stenosis: 1-year results from the All-Comers NOTION Randomized Clinical Trial. *J Am Coll Cardiol* 2015; **65**:2184–2194.
8 Reinöhl J, Kaier K, Reinecke H, *et al.* Effect of availability of transcatheter aortic-valve replacement on clinical practice. *N Engl J Med* 2015; **373**:2438–2447.
9 Signorotto P, del Vecchio A, Montorfano M, *et al.* Dosimetric data and radiation risk analysis for new procedures in interventional cardiology. *Radiat Prot Dosimetry* 2010; **142**:201–208.
10 Karambatsakidou A, Omar A, Chehrazi B, *et al.* Skin dose, effective dose and related risk in trascatheter aortic valve implantation (TAVI) procedures: is cancer risk acceptable for younger patients? *Radiat Prot Dosimetry* 2016; **169**:225–231.
11 Sharma D, Ramsewak A, O'Conaire S, *et al.* Reducing radiation exposure during transcatheter aortic valve implantation (TAVI). *Catheter Cardiovasc Interv* 2015; **85**:1256–1261.
12 Hell MM, Biburger L, Marwan M, *et al.* Prediction of fluoroscopic angulations for transcatheter aortic valve implantation by CT angiography: influence on procedural parameters. *Eur Heart J Cardiovasc Imaging* 2016; **18**:906–914.
13 Deak PD, Smal Y, Kalender WA. Multisection CT protocols: sex- and age-specific conversion factors used to determine effective dose from dose-length product. *Radiology* 2010; **257**:158–166.
14 Heron JC. Estimation of effective dose to the patient during medical x-ray examinations from measurements of the dose-area product. *Phys Med Biol* 1992; **37**:2117–2126.
15 Cardis E, Vrijheid M, Blettner M, *et al.* Risk of cancer after low doses of ionising radiation: retrospective cohort study in 15 countries. *BMJ* 2005; **331**:77.
16 Maccagni D, Godino C, Latib A, *et al.* Analysis of a low dose protocol to reduce patient radiation exposure during percutaneous coronary interventions. *Am J Cardiol* 2017; **119**:203–209.
17 Matsumoto S, Yamada Y, Hashimoto M, *et al.* CT imaging before transcatheter aortic valve implantation (TAVI) using variable helical pitch scanning and its diagnostic performance for coronary artery disease. *Eur Radiol* 2017; **27**:1963–1970.
18 Hamdan A, Wellnhofer E, Konen E, *et al.* Coronary CT angiography for the detection of coronary artery stenosis in patients referred for transcatheter aortic valve replacement. *J Cardiovasc Comput Tomogr* 2015; **9**:31–41.
19 Cerrato E, Nombela-Franco L, Nazif TM, *et al.* Evaluation of current practices in transcatheter aortic valve implantation: the WRITTEN (WoRldwIde TAVI ExperieNce) survey. *Int J Cardiol* 2017; **228**: 640–647.